APPLICATION NO. 09/826,118

TITLE OF INVENTION: Wavelet Multi-Resolution Waveforms

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Currently amended CLAIMS

APPLICATION NO. 09/829,118

INVENTION: Wavelet Multi-Resolution Waveforms

INVENTORS: Urbain A. von der Embse

CLAIMS

WHAT IS CLAIMED IS:

Claim 1. (deleted)

Claim 2. (deleted)

Claim 4. (deleted)

Claim 5. (deleted_

Claim 6. (deleted)

Claim 7. (currently amended) A least-squares method for ~~implementing~~generating and applying ~~mother~~ Wavelet waveforms and filters ~~for communication applications~~, said method comprising the steps: ~~steps:~~

said ~~mother Wavelet~~Wavelet ~~ψ(n) with sample index n~~ is a digital finite impulse response ~~(FIR)~~ waveform at baseband ~~(zero frequency offset)~~in the time domain,

~~requirements for~~ linear phase ~~FIR~~finite impulse response filter requirements ~~are specified by~~on the passband and stopband performance of the power spectral density ~~(PSD) which requirements~~ are ~~incorporated into~~specified by linear quadratic error metrics ~~J(pass), J(stop),~~ in the Wavelet,

~~Wavelet~~Wavelet requirements on the deadband for quadrature mirror filter ~~(QMF)~~ properties ~~for~~ required for perfect reconstruction are ~~incorporated~~ specified by ~~into the~~ a linear quadratic error metric ~~J(dead),~~ in the Wavelet,

~~Wavelet~~Wavelet orthogonality requirements ~~are expressed by the~~

~~error~~ ~~J(ISI), J(ACI)~~ for intersymbol interference ~~(ISI)~~ and adjacent channel interference ~~(ACI) which~~ are specified by non-linear quadratic error metrics in the Wavelet,

non-linear quadratic error metrics have ~~in said FIR $\psi(n)$ used to control said ISI and ACI levels,~~ quadratic coefficients dependent on the Wavelet,

Wavelet multi-resolution property requires said ~~quadratic~~error metrics to be converted to ~~quadratic~~ error metrics in the discrete ~~Fourier~~Fourier transform ~~harmonics~~harmonics ~~$\psi(k)$ of said $\psi(n)$ wherein k is the harmonic index~~of the Wavelet which harmonics are the Wavelet impulse response in the frequency domain,

using a least-squares recursive solution ~~eigenvalue algorithm~~ algorithm in figures 4,5 with quadratic error metrics, which algorithm requires a means to find the Wavelet harmonics that minimize the sum of said linear quadratic error metrics, an example means being the eigenvalue algorithm,

~~requires the error metrics to be linear forms in the $\psi(k)$ finds the eigenvectors equal to the $\psi(k)$ coefficients which minimize the weighted sum J of said quadratic error metrics,~~

~~step 1 of the iterative algorithm implements said eigenvalue algorithm to find said optimum $\psi(k)$ for the weighted sumsum of J(pass), J(stop), J(dead),~~

~~step 2 linearizes said J(ISI),J(ACI) with said $\psi(k)$ from step 1,~~said harmonics are used to linearize said non-linear quadratic error metrics,

said least-squares recursive solution algorithm finds the harmonics which minimize the weighted sum of the linear and linearized quadratic error metrics,

~~step 4 checks to see if said iteration has converged,~~

said least-squares recursive solution algorithm starts over again by using said harmonics to linearize the non-linear error metrics and to find the corresponding harmonics which minimize the sum of said linear and linearized quadratic error metrics,

said least-squares recursive solution algorithm continues to be repeated until the solution converges to the design harmonics of the Wavelet which is the least-squares error solution, and

said Wavelet impulse responses in the time domain and frequency domain are implemented in communication systems for waveforms and filters.

~~step 5 returns to step 2 if said iteration has not converged and linearizes said J(ISI),J(ACI) with said $\psi(k)$ from step 4, and stops iteration if said iteration converges,~~

~~said $\psi(k)$ from said iteration algorithm is the optimum least-squares error solution that minimizes said J,~~

~~use inverse discrete Fourier transform of said $\psi(k)$ to calculate $\psi(n)$ which minimizes J,~~

~~use said $\psi(n)$ for the transmitted data symbol waveform in the communications transmitter and,~~

~~use complex conjugate of said $\psi(n)$ for the impulse response of the detection filter in the communications receiver to remove the received $\psi(n)$ and recover said transmitted data symbols.~~

Claim **8.** (currently amended) ~~A second~~ A second ~~method for~~ least-squares method for generating and applying Wavelet waveforms and filters, said method comprising the steps: ~~implementing mother Wavelet waveforms and filters for communication applications, said method comprising construct said error metrics J(pass),J(stop), J(dead),J(ISI),~~

~~J(ACI) as quadratic error metrics in ψ(k) as depicted in claim 7 and convert these quadratic forms to norm-squared error metrics in ψ(k) for least-squares gradient solution and construct J as their weighted sum,~~

linear phase filter requirements on the passband and stopband performance of the power spectral density are specified by linear quadratic error metrics in the Wavelet impulse response in the time domain,

using a least-squares recursive solution algorithm in figures 4,5 with norm-squared error metrics, which algorithm requires a initialization Wavelet and a means to find the Wavelet harmonics which minimize the sum of said linear norm-squared error metrics, an example means being a gradient search algorithm,

~~step 1 calculates an initial estimate ψ(k) of said solution using~~

said initialization Wavelet is the ~~Remez-Exchange algorithm~~ optimum Wavelet that minimizes the weighted sum of said linear quadratic error metrics which optimum Wavelet is found using an eigenvalue, Remez-Exchange, or other optimization algorithm,

~~for the weighed sum of~~

~~J(pass), J(stop) represented as quadratic error metrics in ψ(k),~~

said linear quadratic error metrics are transformed into linear norm-squared error metrics in the Wavelet,

Wavelet requirements on the deadband for quadrature mirror filter properties required for perfect reconstruction are specified by a linear norm-squared error metric in the Wavelet,

Wavelet orthogonality requirements for intersymbol interference and adjacent channel interference are specified by non-linear norm-squared error metrics in the Wavelet,

~~step 2 uses said estimate ψ(k) from step 1 to initialize said~~

~~gradiant algorithm,~~

~~step 3 selects one of several available gradient search algorithms, gradient search parameters, and stopping rules,~~

~~step 4 implements said algorithm, parameters, and stopping rule selected to derive said optimum ψ(k) to minimize J equal to the sweighted sum of the norm-squared error metrics J(pass), J(stop), J(dead), J(ISI), J(ACI),~~

non-linear norm-squared error metrics have norm coefficients dependent on the Wavelet,

Wavelet multi-resolution property requires said error metrics to be converted to error metrics in the discrete Fourier transform harmonics of the Wavelet which harmonics are the Wavelet impulse response in the frequency domain,,

using said least-squares recursive solution algorithm to find the harmonics that minimize the weighted sum of said least-squares linear and non-linear norm-squared error metrics, which harmonics are the design harmonics of the Wavelet least-squares error solution, and

said Wavelet impulse responses in the time domain and frequency domain are implemented in communication systems for waveforms and filters.

~~use inverse discrete Fourier transform of said ψ(k) to calculate ψ(n) which minimizes J,~~

~~use said ψ(n) for the transmitted data symbol waveform in the communications transmitter and,~~

~~use complex conjugate of said ψ(n) for the impulse response of the detection filter in the communications receiver to remove the received ψ(n) and recover said transmitted data symbols.~~

~~a)~~Claim **9.** (deleted)

Claim **10.** (currently amended) ~~A method for implementing~~Wherein applications of the Wavelet waveforms and filters ~~for multi-resolution communication applications derived from said mother Wavelet~~in claims 7 or 8, ~~s in claims 7 or 8,~~ comprising: ~~steps:~~

~~said mother Wavelet is designed for application to an M channelpolyphase filter bank as depicted in claims 7 or 8 wherein~~

Wavelet design in the frequency domain allows a mother Wavelet to be re-scaled for application to multi-channel polyphase filter banks by implementing equations (11),(18),(20) which derive a multi-resolution Wavelet from a mother Wavelet by using the design harmonics of the mother Wavelet and the multi-scale parameters of the Wavelet impulse response for said application,

wherein mother Wavelet refers to a Wavelet at baseband which is used to generate other Wavelets,

wherein multi-scale parameters are the traditional scale, translation, timing parameters, plus the new frequency, spacing, and length parameters of this invention,

scale parameter scales the sampling time interval, the sub-sampling, the over-sampling, and the translation interval between Wavelets,

translation parameter is the timing offset of the Wavelets in units of the spacing parameter,

timing parameter is the digital sampling interval,

frequency parameter is a frequency offset which translates the Wavelet in frequency,

spacing parameter is the number of digital samples for Wavelet spacing which is equal to the number of channels in a polyphase filter bank with a Nyquist sampling rate,

length parameter specifies the length of the Wavelet in the sampling domain, and

said multi-scale parameters and the mother Wavelet design harmonics generate the Wavelet for the multi-channel polyphase filter bank.

~~M is the spacing between Wavelets within said channels for the Nyquist digital filter bank sample rate 1/T,~~

~~said multi-resolution changes the number of said user channels to M2^p while keeping the same channel filter design which means said Nyquist digital sample rate is changed to 2^p/T wherein Wavelet scale parameter p is an integer,~~

~~said multi-resolution Wavelet FIR $\psi(n)$ is derived from said mother Wavelet design harmonics $\psi(k)$ using the inverse discrete Fourier transform for the mapping of $\psi(k)$ to $\psi(k)$,~~

~~use said $\psi(n)$ for the transmitted data symbol waveform for each transmit channel in the communications transmitter and,~~

~~use complex conjugate of said $\psi(n)$ for the impulse response of the detection filter bank in the communications receiver which is used to remove the received $\psi(n)$ and recover said transmitted data symbols.~~

Claim **11**. (deleted)

Claim **12**. (~~new~~currently amended) Wherein ~~said Wavelet~~properties of Wavelet waveforms and filters in claims 7 or 8, ~~in claims 7,8,or 10 have properties~~ comprising:

said ~~multi-resolution~~Wavelets are multi-resolution Wavelets which enable a single Wavelet design at baseband to be used to generate ~~Wavelets $\psi(n)$ at baseband are derived from said mother Wavelet~~Wavelets for multi-resolution applications by implementing equations (11),(18)(20) and using ~~said~~ the Wavelet design ~~harmonics~~harmonics ~~$\psi(k)$~~ and the multi-scale ~~scale~~ parameters for the multi-resolution

Wavelet applications, ~~said dilation p, said number of samples M over Wavelet spacing, length (L) in units of M, said digital sample rate 1/T, and translation parameter.~~

said ~~ψ(n)~~Wavelet can be designed ~~to support a bandwidth~~for a communications waveform with ~~(B) time(T)~~ ~~with~~ no excess —bandwidth ~~α=0~~,

said multi-resolution ~~Wavelet~~Wavelets are designed to behave like an accordion in that at different scales ~~said~~ the Wavelet~~s~~ ~~are~~is a stretched ~~and~~ or compressed version~~s~~ of the ~~mother Wavelet~~Wavelet with appropriate time and frequency translation~~,~~ as disclosed on page 21,

said linear waveform and filter least—squares design methods can be modified to design non-linear Wavelet waveforms for other applications including bandwidth efficient modulation and synthetic aperture radar as demonstrated in figures 7,8, —and~~,~~

other optimization algorithms exist for finding said Wavelets. — ~~optimum ψ(n).~~